

3. Bioacoustic survey; submitted by Jennifer H. Emery (Leg I & II), Roger P. Hewitt (Leg I), and David A. Demer (Leg II).

3.1 Objectives: The primary objectives of the bioacoustic survey during Legs I and II were to: (1) map the meso-scale dispersion of krill in the vicinity of the South Shetland Islands; (2) to estimate their biomass; (3) and to determine their association with predator foraging patterns, water mass boundaries, spatial patterns of primary productivity, and bathymetry.

3.2 Methods and Accomplishment: Acoustic data were collected using a multi-frequency echo sounder (Simrad EK500) configured with down-looking 38, 120, and 200 kilohertz (kHz) transducers mounted in the hull of the ship. System calibrations were conducted before and after the surveys using standard sphere techniques while the ship was at anchor south of Elephant Island near Endurance Glacier and in Admiralty Bay, King George Island. During the surveys, pulses were transmitted every 2 seconds at 1 kilowatt for 1 millisecond duration at 38kHz, 120kHz, and 200kHz. Geographic positions were logged every 60 seconds. Ethernet communications were maintained between the EK500 and two Windows 2000 workstations. Both Windows 2000 workstations were running SonarData EchoLog and EchoView software. One unit was used for primary system control, and data logging, processing and archiving while the other ran in parallel for back-up logging and archiving.

Acoustic surveys of the water surrounding the South Shetland Islands were conducted on Legs I and II. These surveys were divided into four areas (See Figure 2 in Introduction): (1) a 43,865km² area centered on Elephant Island (Elephant Island Area) was sampled with seven north-south transects; (2) a 38,524km² area along the north side of the southwestern portion of the South Shetland archipelago (West Area) was sampled with six transects oriented northwest-southeast and one oriented north-south; (3) a 24,479km² area in the western Bransfield Strait (South Area) was sampled with six transects oriented northwest-southeast; and (4) an 18,151 km² area north of Joinville Island (Joinville Island Area) was sampled with three transects oriented north-south.

A faulty high-voltage power supply was discovered during the first half of Survey A. A new power supply was installed and the EK500 echosounder was re-calibrated.

3.2.1 Krill Delineation Legs I and II (Survey D):

Krill densities were estimated using a three-frequency delineation method as opposed to the two-frequency method used in past research (Madureira *et al.*, 1993). This method reduced the inclusion of other euphausiid species and myctophid fish in the biomass estimate. A Δ MVBS (mean volume backscattering strength) window of 4 to 16dB was set as the acceptable difference between the 120kHz and 38kHz data for labeling acoustic target as krill. However, this preset criteria allowed the inclusion of a small amount of myctophids in the final krill density estimate. Therefore a second Δ MVBS window of -4 to 2dB was established as the acceptable difference between the 120kHz and 200kHz transducer data in which backscattering values would be attributed to krill. The combined application of these two windows (three-frequency method) eliminated all acoustic targets not classified as Antarctic krill (Figure 3.1). The window ranges

were selected based on models of krill backscattering strength at each frequency (Demer, in press).

3.2.2 Abundance Estimation and Map Generation:

Backscattering values were averaged over 5m by 100s bins. Time varied noise was subtracted from the echogram and the Δ MVBS window was applied. The remaining volume backscatter classified as krill (S_v) was integrated over depth (500m) and averaged over 1852m (1 nautical mile) distance intervals. These data were processed using SonarData Echoview software.

Integrated krill nautical area scattering coefficient (NASC) (MacLennan and Fernandes, 2000) was converted to estimates of krill biomass density (ρ) by applying a factor equal to the quotient of the weight of an individual krill and its backscattering cross-sectional area, both expressed as a function of body length and summed over the sampled length frequency distribution for each survey (Hewitt and Demer, 1993):

$$\rho = 0.249 \sum_{i=1}^n f_i(l_i)^{-0.16} \text{NASC} \quad (\text{g/m}^2)$$

Where

$$\text{NASC} = 4\pi (1852)^2 \int_0^{500} S_v \quad (\text{m}^2/\text{n.mi.}^2)$$

And f_i = the relative frequency of krill of standard length l_i .

For each area in each survey, mean biomass density attributed to krill and its variance were calculated by assuming that the mean density along a single transect was an independent estimate of the mean density in the area (Jolly and Hampton, 1990).

3.3 Tentative Conclusions: During Survey D (Leg II), the highest concentration of krill was mapped north of Livingston Island along the shelf break (Figure 3.2). High concentrations of krill were also found northeast of King George Island/west of Elephant Island, north of Clarence Island, and in the Bransfield Strait west of Deception Island and northwest of the Antarctic Peninsula. Krill scattering layers were typically found between 50m and 250m. Krill density estimates are listed by areas and transect in Table 3.2.

Mean krill biomass densities within the ten years of the AMLR surveys were highest in 1996/97 and lowest in 2001/02 (Table 3.1). The historical U.S.-AMLR acoustic data collected in the Elephant Island Area has recently been re-processed with the three-frequency method (Hewitt *et al.*, in press). A model of the variability of acoustic estimates of krill in the Elephant Island Area predicts increasing krill density in 2002/03 (Figure 3.3). This approach is considered more conservative compared to application used in past research and reduces the possibility of over-estimating krill biomass, but may also exclude some less aggregated krill swarms.

Survey A (Leg I) krill densities are presented as a range (Tables 3.1 and 3.2). The two values represent data processed with settings obtained during the initial calibration with the faulty power supply versus data processed with settings obtained during the calibration following the installation of the new power supply. Because of the compromised integrity of this data, no distribution map is presented for Survey A.

3.4 Disposition of Data: All integrated acoustic data will be made available to other U.S. AMLR investigators in ASCII format files. The analyzed echo-integration data consume approximately 10 Mbytes. The data are available from Jennifer H. Emery, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037; phone/fax – (858) 546-5609/546-5608; e-mail: Jennifer.Emery@noaa.gov.

3.5 References:

Demer, D.A. In press. An estimate of error for the CCAMLR 2000 estimate of krill biomass. *Deep Sea Research II, Special issue*.

Hewitt, R.P., Demer, D.A., and Emery, J.H. In press. An eight year cycle in krill biomass density inferred from acoustic surveys conducted in the vicinity of the South Shetland Islands during the austral summers of 1991/92 through 2001/02. *ICES Journal of Marine Science*.

Hewitt, R.P. and D.A. Demer. 1993. Dispersion and abundance of Antarctic krill in the vicinity of Elephant Island in the 1992 austral summer. *Maine Ecology Progress Series* 99: 29-39.

Jolly, G.M. and I. Hampton. 1990. A stratified random transect design for acoustic surveys of fish stocks. *Canadian Journal of Fisheries Aquatic Science* 47: 1282-1291.

MacLennan, H. and Fernandes, P. Definitions, units and symbols in fisheries acoustics. Draft 03/04/00. Contr FAST Working Group Meeting, Haarlem, April 2000, 6p.

Maduriera, L.S.P., Ward, P., and Atkinson, A. 1993. Differences in backscattering strength determined at 120 and 38 kHz for three species of Antarctic macroplankton. *Marine Ecology Progress Series* 99: 17-24.

Table 3.1. Mean krill biomass density for surveys conducted from 1992 to 2002. Coefficients of variation (CV) are calculated by the methods described in Jolly and Hampton, 1990, and describe measurement imprecision due to the survey design. 1993 estimates were omitted due to system calibration uncertainties; only one survey was conducted in 1996/97; 1998/99 South Area values are not available due to lack of data. See Figure 2 in the Introduction Section for description of each survey area.

Survey	Area	Mean Density (g/m ²)	Area (km ²)	Biomass (10 ³ tons)	CV %
1992 A (late January)	Elephant Island	61.20	36,271	2,220	15.8
D (early March)	Elephant Island	29.63	36,271	1,075	9.2
1994 A (late January)	Elephant Island	9.63	41,673	401	10.7
D (early March)	Elephant Island	7.74	41,673	323	22.2
1995 A (late January)	Elephant Island	27.84	41,673	1,160	12.0
D (early March)	Elephant Island	35.52	41,673	1,480	24.2
1996 A (late January)	Elephant Island	80.82	41,673	3,368	11.4
D (early March)	Elephant Island	70.10	41,673	2,921	22.7
1997 A (late January)	Elephant Island	100.47	41,673	4,187	21.8
1998 A (late January)	Elephant Island	82.26	41,673	3,428	13.6
	West	78.88	34,149	2,694	9.9
	South	40.99	8,102	332	16.3
D (late February)	Elephant Island	47.11	41,673	1,963	14.7
	West	73.32	34,149	2,504	16.6
	South	47.93	8,102	388	12.2
1999 A (late January)	Elephant Island	23.72	41,673	988	20.3
	West	27.13	34,149	927	28.7
	South	19.68	8,102	159	9.4
D (late February)	Elephant Island	15.37	41,673	641	26.0
	West	11.85	34,149	405	30.0
	South	N/A	8,102	N/A	N/A
2000 D (late February)	West	37.54*	34,149	1,282	14.1
	Elephant Island	36.19*	41,673	1,508	21.1
	South	22.75*	8,102	184	29.2
2001 A (late January)	West	16.98 [†]	34,149	580	22.5
	Elephant Island	15.57 [†]	41,673	649	13.9
	South	12.64 [†]	8,102	102	22.2
D (late February)	West	16.26 [†]	34,149	555	33.9
	Elephant Island	12.77 [†]	41,673	532	11.6
	South	9.59 [†]	8,102	78	40.1
2002 A (late January)	West	0.57-5.54 ^{‡‡}	38,524	22-213	52.6, 44.7
	Elephant Island	1.71-4.07 ^{‡‡}	43,865	75-178	58.3, 19.3
	South	1.27-1.80 ^{‡‡}	24,479	31-44	51.4, 40.6
	Joinville Island	1.05 ^{‡‡}	18,151	19	9.2
D (late February)	West	0.92 ^{‡‡}	38,524	35	62.1
	Elephant Island	0.84 ^{‡‡}	43,865	37	18.9
	South	0.80 ^{‡‡}	24,479	20	27.1
	Joinville Island	0.51 ^{‡‡}	18,151	9	73.3

*Data values are based on the two-frequency krill delineation method.

[†]Data values are based on the three-frequency krill delineation method (2-14dB difference between 120 and 38kHz and 0-5dB difference between 200 and 120kHz).

^{‡‡} Data values are based on the three-frequency krill delineation method (4-16dB difference between 120 and 38kHz and -4-2dB difference between 200 and 120kHz).

All other density measurements within this table are based on total volume backscatter.

Table 3.2. Krill density estimates by area and transect for Surveys A and D, Legs I and II

Elephant Island Area			
		Survey A	Survey D
	n	krill density	krill density
Transect 1	105	0.19-2.16	0.38
Transect 2	92	0.07-3.37	0.42
Transect 3	117	0.23-5.54	1.29
Transect 4	97	0.25-5.79	0.58
Transect 5	138	6.52-6.79	1.00
Transect 6	90	1.08-1.08	0.59
Transect 7	101	3.03-3.08	1.43
West Area			
		Survey A	Survey D
	n	krill density	krill density
Transect 1	42	1.09-15.72	0.14
Transect 2	45	2.49-18.29	0.17
Transect 3	41	1.20-4.86	0.08
Transect 4	63	0.06-0.81	3.87
Transect 5	64	0.00-2.12	1.36
Transect 6	62	0.29-4.66	0.15
Transect 7	89	0.04-0.63	0.16
South Area			
		Survey A	Survey D
	n	krill density	krill density
Transect 1	56	0.61	1.01
Transect 2	43	1.12	0.00
Transect 3	41	0.34	0.80
Transect 4	22	7.38	0.02
Transect 5	43	1.41	1.16
Transect 6	40	0.09-3.30	1.39
Joinville Island Area			
		Survey A	Survey D
	n	krill density	krill density
Transect 1	61	1.07	1.28
Transect 2	59	1.22	0.12
Transect 3	48	0.82	0.00

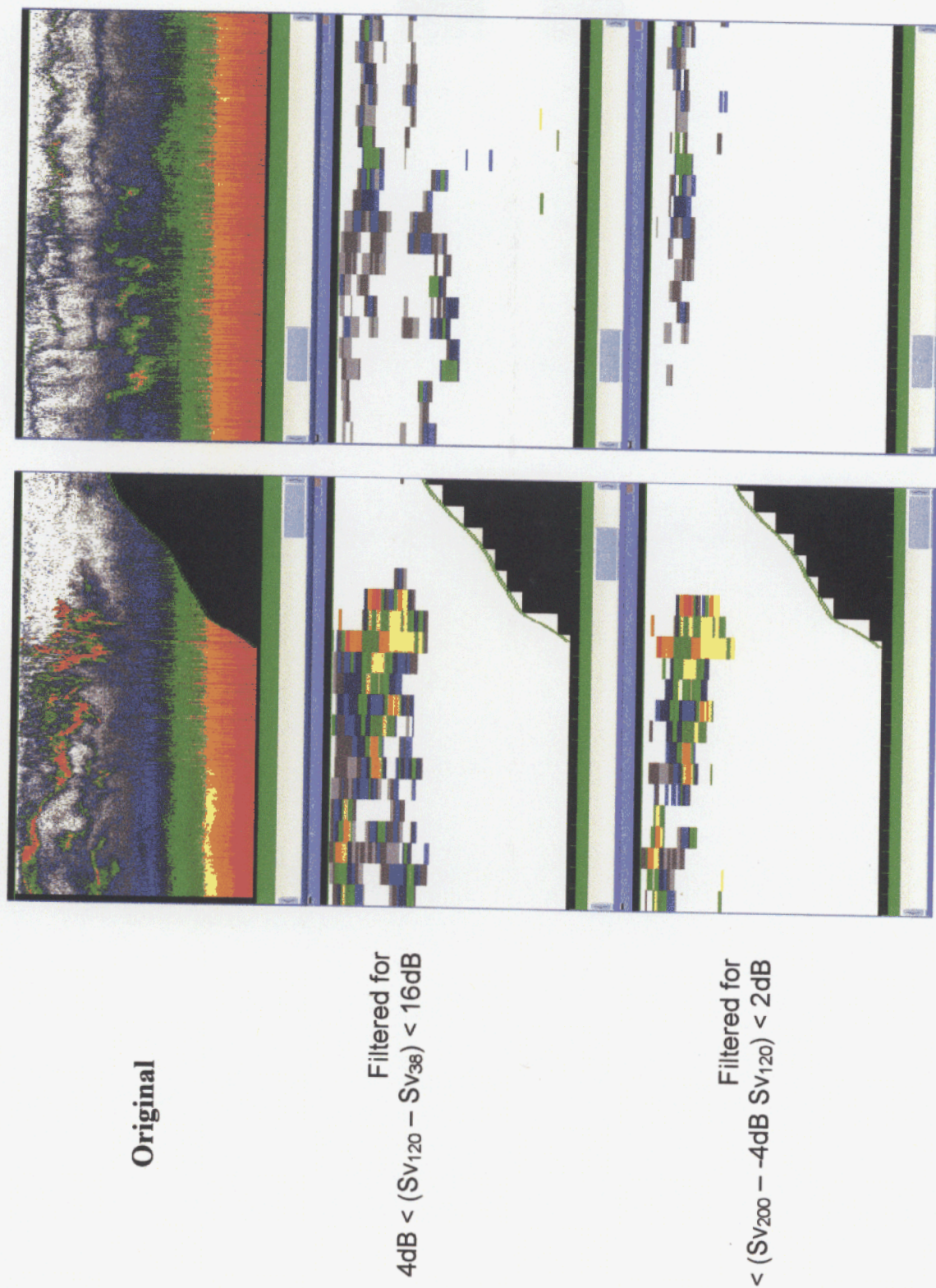


Figure 3.1. Two examples of 120kHz echograms representing the three-frequency method of krill delineation.

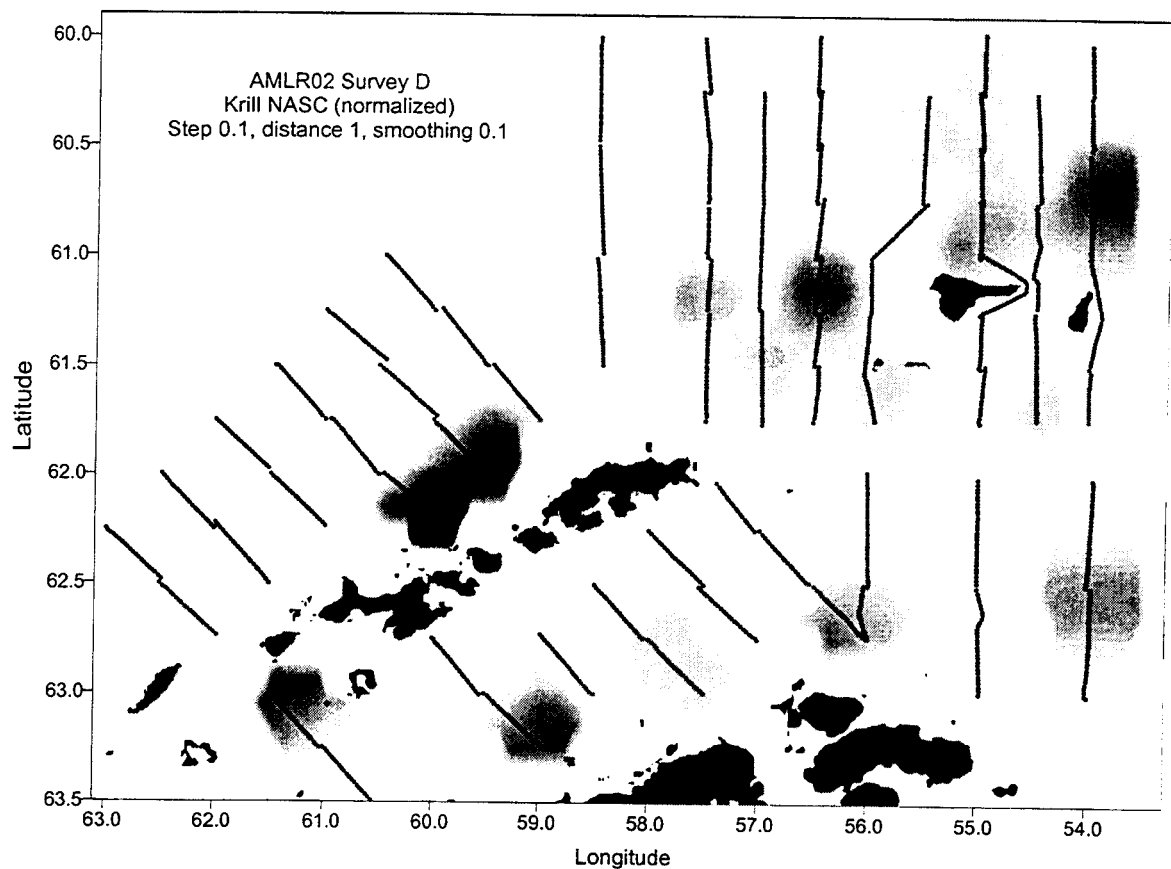


Figure 3.2. Distribution of sample-weighted krill NASC ($\text{m}^2/\text{n.mi.}^2$) for Survey D collected at 120kHz. Parameters refer to 'track and fields' software settings used for smoothing. Dark areas are indicative of high concentrations of krill.

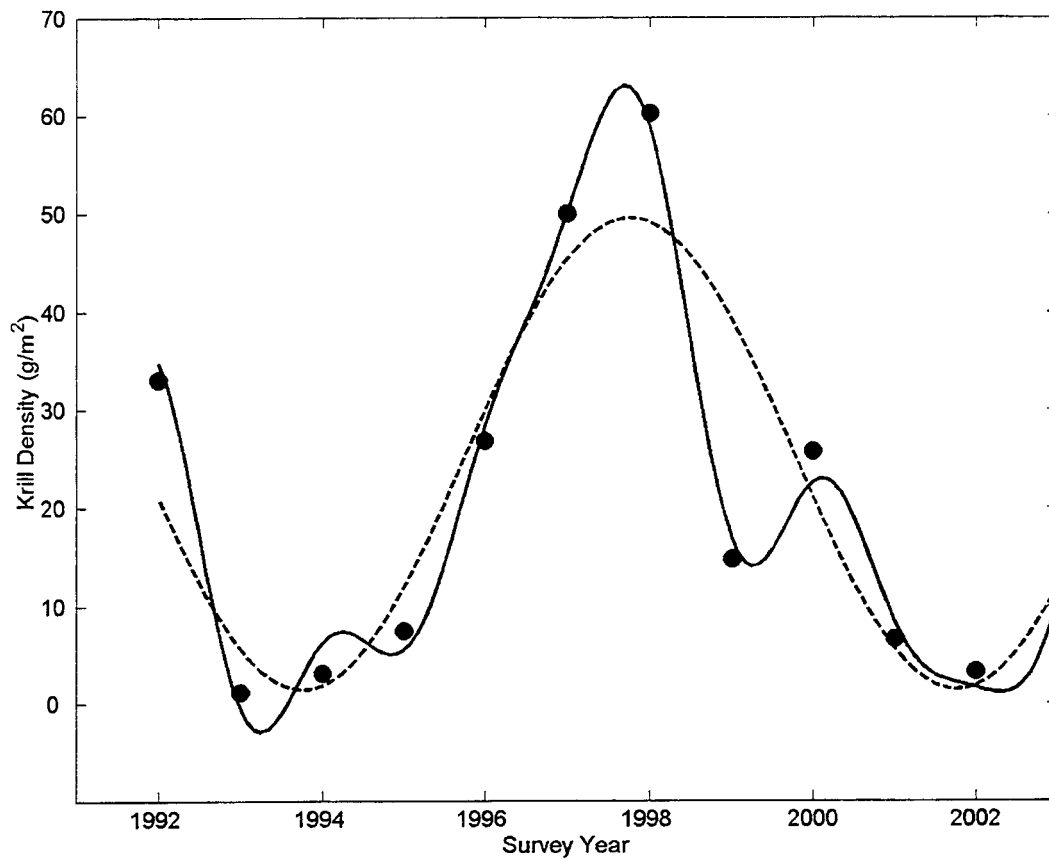


Figure 3.3. Time series of krill biomass density in the Elephant Island Area from January 1991/92 to 2001/2002 using a three-frequency method to delineate volume backscattering from krill (Hewitt *et al.*, in press). The solid line represents a truncated Fourier series fit to the data and indicating dominant cycles at 3 and 8 years. The dark line indicates an 8-year cycle fit to the time series.